Nuclear-powered submarines

Backgrounder

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Nuclear-Powered Submarines: Potential Environmental Effects

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NUCLEAR-POWERED SUBMARINES: POTENTIAL ENVIRONMENTAL EFFECTS

INTRODUCTION

The proposed acquisition of nuclear-powered submarines by the Canadian Armed Forces raises a number of legitimate concerns, including that of their potential impact on the environment. The use of nuclear reactors as the propulsion units in these submarines merits special consideration, for obvious reasons. Radioactivity, as an environmental pollutant, has unique qualities and, moreover, engenders particular fears among the general population. Though some of these fears may be based upon lack of knowledge of the technology involved, or a misunderstanding of the potential for serious accident, the basic concerns about radiation-induced illnesses and ecological effects are well-founded.

The effects of nuclear-powered submarines on the environment fall into two distinct categories: those deriving from normal operations of the submarine (the chief concern of this paper), and those deriving from a reactor accident.

THE REACTOR ACCIDENT

One fear that may be harboured by members of the general public is that the reactor of the nuclear-powered submarine is "an atomic bomb waiting to explode." Although a reactor core melt-down, for example, is an extremely serious event, it is not equivalent to a nuclear explosion. In fact, the reactor in a nuclear-powered submarine cannot explode like a bomb; the reactor core is so designed that this is a physical impossibility.

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A reactor accident may be defined as an unexpected event which is likely to lead to, or has resulted in, a radiological hazard external to the actual reactor. The most serious reactor accident for which protection mechanisms can be designed is the maximum design accident, or MDA. This is defined as a loss of primary coolant beyond make-up capacity, leading to core melt-down and the release of fission products. The more severe possible accidents, for example the failure of the reactor pressure vessel, are not covered by the protection mechanisms in a nuclear-powered submarine.

A reactor accident would release large amounts of dangerous radioactivity, the effects of which would depend on a number of variables, including the location of the accident (whether in port or at sea), the containment state of the submarine, the weather conditions (particularly the wind direction and speed) and the operational state of the reactor plant at the time of the accident.

This last factor, the reactor plant state, is very important in an accident scenario. In the normal sea-going state, Plant State A, the submarine's pressurized water reactor (PWR) operates at high temperature and pressure. It is in this state that a catastrophic rupture of the plant pipework is most likely to happen, leading to a reactor accident. It must be emphasized, however, that the probability of such an accident is extremely small; none, in fact, has ever occurred on a nuclear submarine.

The probability of failure of the plant pipework is much less, and indeed becomes effectively zero, when the pressure and temperature of the PWR are similarly reduced, an operational state known as Plant State B. This is the normal state of the PWR during docking procedures in harbour.

Therefore, we may conclude that the highest probability of a reactor accident exists when the submarine is operating at full power in the open sea, typically away from population centres and sensitive environmental areas. The corollary is that the likelihood of a reactor accident is lowest when the consequences of that accident would be most serious.

RADIOACTIVITY RELEASES FROM NUCLEAR VESSELS

The principal concern about environmental effects caused by nuclear-powered submarines, however, relates to the release of radioactivity during normal operations and maintenance. Both the type and amount of radiation are important considerations. In the context of this discussion, it must be recognized that radiation from a man-made source may have to be weighed against a quantity of similar "background" radiation; that is, radiation present in the natural environment. In some cases, such radiation is of significant magnitude.

The data included in this section of the paper are from the United States Navy (USN), as presented to the Procurement and Military Nuclear Systems Subcommittee of the House of Representatives Committee on Armed Services.(1) These congressional hearings are an annual event. The data cited are from an appendix to the actual hearings, in the form of an annual report.(2)

The radioactivity in materials of concern originates in the PWRs of nuclear-powered ships, principally submarines. At the end of 1985, the USN had a total of 147 nuclear-powered vessels, including 134 submarines. Support facilities for this fleet included eight shipyards, seventeen tenders, and four submarine bases which were involved in construction, maintenance, overhaul and refuelling.

The environmental monitoring report claims that since the start of the naval nuclear propulsion program in the mid-1950s, the USN has been able to reduce radioactivity releases progressively to a minimum

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(1) United States Congress, Naval Nuclear Propulsion Program - 1987, Hearing on H.R.4526 [H.R.4428], Department of Energy National Security Programs Authorization Act for Fiscal Years 1987 and 1988, before the Procurement and Military Nuclear Systems Subcommittee of the Committee on Armed Services, House of Representatives, 99th Congress, 2nd Session, February 20, 1986, U.S. Government Printing Office, Washington, D.C.

(2) J.J. Mangeno, D.H. Rushworth and B.F. Harvey, Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1985, Report NT-86-1, February 1986. Approved by Admiral K.R. McKee, USN, Director, Naval Nuclear Propulsion Program. (Appendix A to Reference #1, above)

through the adoption of new procedures, standards and regulations. The total gamma radioactivity[3] released within 12 miles of shore from all USN nuclear-powered ships and their support facilities between 1971 and 1985 is claimed to have been less than 0.002 curies per year.[4] The report states: "As a measure of the significance of these data, if one person were able to drink the entire amount of radioactivity discharged into any harbor in any of (these fifteen) years, he would not exceed the annual radiation exposure permitted for an individual worker by the U.S. Nuclear Regulatory Commission." The total radioactivity released into the open sea more than 12 miles from shore is stated to be 0.4 curies per year. These two figures exclude radioactivity from tritium and carbon 14, both of which are discussed below.

The principal source of radioactivity in liquid wastes comes from trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with reactor coolant water. A variety of radioactive elements, or radionuclides, is produced. The predominant radionuclide with a half-life greater than one day is cobalt 60, which has a half-life of 5.3 years.[5]

The reactor coolant water also contains radionuclides with very short half-lives ranging from seconds to hours. This group includes such species as nitrogen 16 (7 second half-life), argon 41 (1.8 hour half-life), and manganese 56 (2.6 hour half-life). For the longest-lived of this group, the concentration in water is reduced, within about 24 hours, to one-thousandth of the initial concentration.

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(3) Gamma rays are emitted by the nucleus of a radioactive element and are basically the same as x-rays, but generally have more energy. Gamma rays can travel great distances through the air and can sometimes penetrate quite deeply into the human body. Since gamma radiation is ionizing radiation, it has the potential to cause harm to living organisms, if the dose is high enough.

(4) Named for M^{me} Marie Curie, a "curie", or Ci, is a measure of radioactivity, or the rate at which radioactive material disintegrates. Thus 1 Ci is equal to 37 billion disintegrations per second, approximately the radioactivity of one gram of radium 226.

(5) The "half-life" of the radionuclide is the time for its radioactivity to decrease to half of its original value.

Fission product radionuclides produced in the reactor itself are retained in the fuel elements, including the fission gases krypton and xenon. Some fission products are released into the reactor coolant, with the longest-lived species being strontium 90 and cesium 137. The USN claims that the volumes of reactor coolant released into the environment are so low that the total radioactivity attributable to strontium 90 and cesium 137 is less than 0.001 Ci per year for all harbours combined.

Tritium, another radioactive element formed in reactor coolant systems, has a half-life of 12.3 years but the radiation emitted is in the form of beta particles of very low energy. Also, tritium is a natural component of the environment, being formed as a result of cosmic radiation in the upper atmosphere. The report by Mangeno et al. states that this natural source of tritium totals some four million Ci per year, and that the inventory of tritium in the world's oceans as a result of rainfall is about 70 million Ci. It also states that the entire USN nuclear fleet releases less than 200 Ci of tritium per year. Assuming these various figures (including the estimated release of tritium from naval reactors) are correct, the discharge of tritium from a nuclear-powered submarine under normal operating conditions should be insignificant in terms of overall environmental impact. One cannot, of course, rule out the possibility of local detrimental effects from an accidental spill.

Carbon 14 is formed in small quantities in reactor coolant systems and has a half-life of 5,730 years. However, it emits only low-energy beta radiation during the decay process and, also, is commonly found in the natural environment. Mangeno et al. state that the earth's total carbon 14 inventory is about 250 million Ci, while the USN nuclear fleet is claimed to release less than 100 Ci annually. Assuming these figures also are accurate, the environmental impact of carbon 14 released annually from nuclear-powered vessels should be negligible, with the exclusion again of possible local detrimental effects.

ENVIRONMENTAL SAFEGUARDS

The testimony presented to the United States Congress by the United States Navy and summarized above, is reassuring in terms of the environmental impact of nuclear-powered submarines under normal operating conditions. Perhaps, however, two cautionary points can be raised.

First, it has to be accepted that unintentional releases of radioactivity, even exclusive of a reactor accident, are possible. Implicit in the data presented by the USN, however, is the suggestion that there have been no such releases of radioactivity during the operations of nuclear warships, at sea or within 12 miles of shore. This could mean that submarine operational procedures are so exacting, and crews so well-trained, that accidents do not occur. On the other hand, it could mean that accidents of this type are simply not made public by the military as a matter of policy.

It should be noted that catastrophic accidents have occurred on board nuclear submarines. The USN has, in fact, lost two nuclear submarines, the THRESHER and the SCORPION, in the Atlantic Ocean, the former in April 1963 and the latter in May 1968. Neither disaster was reported to have involved a reactor accident, however. Also, it should be emphasized that two decades have now elapsed since the loss of the SCORPION, an indication, perhaps, of continual improvement in operational procedures and safeguards.

There have also been unofficial reports of accidents involving nuclear submarines, including accidental releases of radioactivity. The (U.S.) Center for Investigative Reporting published a survey in 1983 alleging that such accidents are fairly common.

An article by David E. Kaplan, which summarizes the 1983 survey, states:

- Serious problems have befallen U.S. naval reactors..., including at least thirteen accidental discharges of radioactive material in coastal areas.

- Nuclear vessels frequently encounter difficulties which could lead to nuclear accidents, including floods, fires and mechanical breakdowns. Although most of these incidents go unreported, a 1983 survey by the

> Center for Investigative Reporting revealed 126 since 1954...Over one-quarter of the events involved problems related to the nuclear power plant.(6)

The USN has denied the claims by the Center for Investigative Reporting.(7) Whether these claims are accurate or not is an important consideration, inasmuch as they may reflect on the inherent reliability of nuclear-powered submarines.

A Canadian nuclear fleet would need extensive and complex shore facilities, including one or more operating bases and at least one refit base. These bases would handle nuclear fuel and other radioactive materials and would therefore be potential sources of environmental contamination.

An operating base would have facilities for running repairs and minor maintenance and, possibly, a training plant. It has been suggested that an operating base would be required on each of the Atlantic and Pacific coasts. One of these bases could be combined with the refit base and would be the site for overhauls and major repairs. East coast candidates include Halifax, Saint John, New Brunswick, and St. John's and Argentia, Newfoundland. The west coast possibilities include Vancouver, Esquimalt and Prince Rupert.(8)

It is clear that a complex system of procedures would have to be designed to handle the nuclear fuel cycle, from the mining of the uranium, to the processing and shipping of the fuel, and to the collection, treatment and disposal of solid and liquid wastes from the submarines themselves. To back up this network, it would be necessary to establish a

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(6) David E. Kaplan, "When Incidents Are Accidents: The Silent Saga of the Nuclear Navy," Oceans, Volume 16, No. 4, July-August 1983, pp. 26-33.

(7) Navy Response to the Article Entitled "The Nuclear Navy," July 20, 1983; and Setting the Record Straight - Allegations and Reactions (From Sea Power, September 1983, by Vincent C. Thomas, Jr.) Appendix D to: United States Congress, Naval Nuclear Propulsion Program - 1984, Hearing on HR5263 [H.R.5395], February 28, 1984.

(8) Richard L. Donaldson, "Basing the SSN Fleet," Wings Magazine, CASAP, 1988, pp. 51-54.

comprehensive system of environmental monitoring and controls, including technologies and personnel capable of dealing with emergency situations.

The obvious question at this point is whether the entire system would be under the mandate of the Department of National Defence, or whether civilian agencies, such as Environment Canada and the relevant provincial departments, would be involved, and if so to what extent. A second question concerns information gathered by the environmental monitoring system, regardless of who operated and established it. Would this information be available to the public, or would it be classified in the name of national security?

Nuclear-powered submarines have been in operation for some three decades, and an enormous body of data must exist, primarily in the United States but also in France and Great Britain, to support their safe and effective operation. It must be assumed that there is also extensive information on the environmental impact of the operations of these submarines. As yet, however, little information on this aspect of the proposed submarine program has been made available to the Canadian public.

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